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A STUDY OF MULTIPLE ACCESS WAVEFORMS WITH ACOUSTIC SURFACE WAVE MATCHED FILTERS

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A STUDY OF MULTIPLE ACCESS WAVEFORMS WITH
ACOUSTIC SURFACE WAVE MATCHED FILTERS

Henry J. Bush

FOREWORD

This report concerns in-house research conducted on wideband waveforms with acoustic surface wave devices. The work was conducted in the Communications-Navigation Techniques Section, Communications Techniques Branch, Communications and Navigation Division, Rome Air Development Center, under Job Order Numbers 45190000 and 692B0000.

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This report has been reviewed by the Information Office, OI, and is releasable to the National Technical Information Service (NTIS).

This technical report has been reviewed and is approved.

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ABSTRACT

This report describes a study into synchronization problems of various spread spectrum waveforms for direct mode, multiple access systems. Particular attention is paid to user mutual interference and how this interference influences the choice of the waveform. Computer generated cross-correlation properties of the 18 basic 127 chip m-sequences are given in simulating a pure code division system.

The basic pseudo-noise sequence is implemented by acoustic surface wave matched filters. The performance of these matched filters under various interference conditions (including multipath) is given.

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I INTRODUCTION

In studying the multiple access problem, one of the main objectives of the modulation method is to minimize the interaction between users. In addition, some form of anti-jam must be maintained, and it is desirable to provide fast transmitter-receiver syncnronization. If one requires the waveform to perform additional functions, the modulation becomes extremely complex. It is generally accepted that these requirements dictate a wideband or spread spectrum system.

The four major modulation techniques applicable are frequency division multiple access (FDMA), pseudo-noise multiple access (PNMA), time division multiple access (TDMA) and pulse-address multiple access (PAMA).[1] Because of their inherently resistant nature, pseudo-noise techniques are usually utilized in hybrid combination with the others. Carrier separability for each of the techniques is denoted in Table I.

In a previous report, the author introduced the idea of utilizing acoustic surface wave multiple tap delay lines to generate and correlate pseudo-noise sequences for application to synchronization preambles for wideband waveforms.[2] The synchronization preamble had been discussed in regard to a wideband, multi-function system[3] and is illustrated in Figure 1.

This report deals with additional experimentation in this area, particularly with the operation of acoustic surface wave matched filters in a multiple access system which contains only direct transmissions without the use of satellite repeaters. This mode of operation increases user mutual interference which enhances the

Table 1. Major Multiple Access Modulation Techniques

MODULATION	SEPARABILITY
FREQUENCY DIVISION (FDMA)	CARRIER FREQUENCY
PSEUDO NOISE (PNMA)	CORRELATION TECHNIQUES
TIME DIVISION (TDMA)	CARRIER TIME
PULSE ADDRESS (PAMA)	TIME-FREQUENCY PULSE PATTERNS

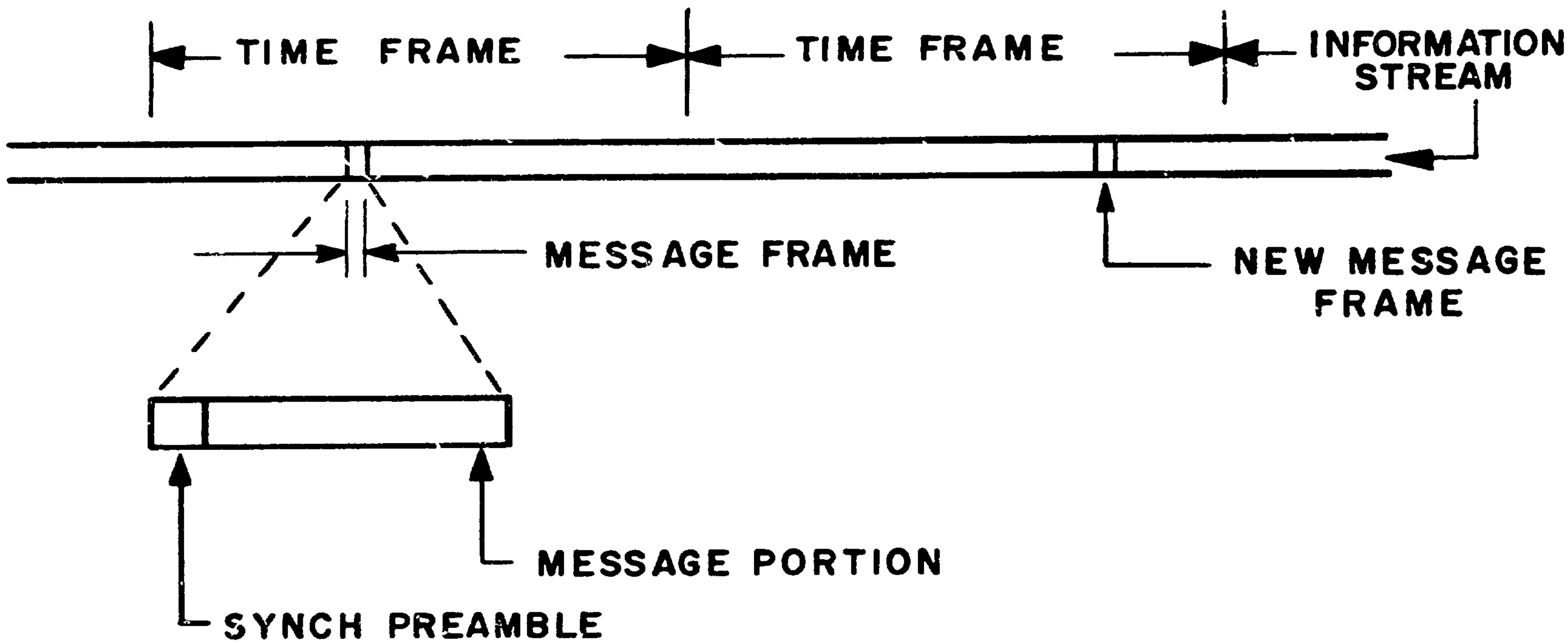


Figure 1. Illustration of the Synch Preamble

importance of the "near-far" problem. That is, the interference problem is of more concern than that of low detectability.

II BASICS OF SPREAD SPECTRUM

Spread spectrum techniques are based upon coherent processing of the information of the received signal and incoherent processing of the noise. The information is spread into a channel bandwidth much wider than the bandwidth needed to pass the information, and transmitted. If the receiver is synchronized with the transmitter and matched to the coding, the information can be collapsed to its original state and recovered, while the noise is spread.

Following Braverman,[4] we can present an illustration of how spread spectrum can provide a 'processing gain' for the information over the noise.

Let s(t) be a narrow-band information bearing signal with average power S watts and bandwidth W_s hertz. Consider a unit amplitude, binary, wide-band coding signal c(t) of bandwidth W_c hertz which is used to encode s(t). If $W_c \gg W_s$, the coded signal c(t)s(t) occupies a bandwidth approximately W_c. If the noise n(t) has average power N in the transmission band W_c, then the received signal is

$$c(t)s(t)+n(t) \qquad (1)$$

The input signal-to-noise at the receiver is

$$\left(S/N\right)_{in} = S/N \qquad (2)$$

The received signal is multiplied by a properly synchronized replica of the binary code c(t) to give a decoded signal

$$c(t)\left(c(t)s(t)+n(t)\right) = s(t)+c(t)n(t) \qquad (3)$$

If $n(t)$ and $c(t)$ are uncorrelated, power in $c(t)n(t)$ will be spread almost uniformly throughout at least a bandwidth of W_c. Since $s(t)$ is confined to a bandwidth W_s, passing the decoded signal, (3), through a narrow band filter of bandwidth W_s, we get

$$s(t)+\bar{n}(t) \tag{4}$$

where $\bar{n}(t)$ is the portion of $c(t)n(t)$ which occupies W_s. Therefore, the noise power at the output of the filter is about $N\,(Ws/Wc)$, and the signal to noise ratio at this point is

$$\begin{aligned}\left(S/N\right)_{out} &= S/\left(NW_s/W_c\right)\\ &= SW_c/NW_s\\ &=\left(S/N\right)_{in}\left(W_c/W_s\right)\end{aligned} \tag{5}$$

If we then define the processing gain by

$$PG = 10\ \log_{10}\left(S/N\right)_{out}/\left(S/N\right)_{in} \tag{6}$$

we get

$$PG = 10\ \log_{10} W_c/W_s \tag{7}$$

Equation (7) illustrates the basic principle of spread spectrum--the percentage of noise power rejected is proportional to the ratio of the bandwidths.

There are two important points to be derived from the above illustration. These are that there must be synchronization between transmitter and receiver, and the coding waveform and the noise must be uncorrelated. As Braverman[4] notes, this reduces the design of a spread spectrum system to the specification of a synchronization procedure and the specification of a secure wideband spread spectrum code.

III PSEUDO-NOISE SYNCH PREAMBLES

1. General Remarks

The use of maximal length binary sequences to provide the preamble coding has been discussed.[2] It was noted that correlation properties produced by a matched filter detector differ from those produced by an active correlator whose integration time corresponds to the length of the maximal length sequence. In essence, the matched filter detector produces correlation sidelobes not encountered with correlation detection. Because of their well-known generating procedure and correlation properties, maximal length binary sequences were considered the most suitable starting point for these investigations. (Braverman[4] has considered composite codes constructed by combining maximal length sequences of various periods.)

The use of matched filters to synchronize a multiple access system requires preambles with good characteristics from two viewpoints.[2] Discrimination of a desired signal from unwanted signals depends on the cross-correlation properties of the preamble sequences used, i.e., the product of one sequence against a second sequence. The exact resolution of synch (epoch time) depends on the auto-correlation properties of the sequences, i.e., the product of a sequence against a time shifted version of itself.

A computer was used to test the cross-correlation properties of the basic eighteen m-sequences of length 127. The results are summarized in Tables 2-11. The 127 chip m-sequence was considered a candidate for synch preambles since, from the 18 basic codes, one can generate 2286 different structures. It has also been thought

that the use of PN sequences can help reduce the effects of multipath. This area was also studied using a multipath simulator.

2. Cross-Correlation Effects

Table 2 presents a listing of the 18 sequences (represented by their generator polynomials) and an index, denoted F_1, which is used to indicate which of the sequences is being correlated against the others. That is, F_1 denotes the reference sequence. The index Lg indicates which sequence is being correlated against the reference. The sequence denoted by a particular Lg changes each time F_1 changes. Thus, $F_1 = 0$, $Lg = 1$ indicates the sequence 1000001 is being correlated against the reference 0000011. Whereas, $F_1 = 8$, $Lg = 1$, denotes the sequence 1100101 is being correlated against the reference 0100111. Also indicated in Table 2 is the burst auto-correlation peak to maximum sidelobe ratio.

Tables 3-11 list the maximum peak for the particular cross-correlation and the position of the peak. The correlation was performed only over the first 127 positions so that one may assume there would be another peak equally spaced beyond the 127th position.

One can note that all peaks are very large and the vast majority are much larger than the maximum auto-correlation sidelobe. In fact in some cases, the peak is 1/3 the size of the auto-correlation peak.

In order to see what this means from an operational point of view, a cross-correlation experiment was conducted with acoustic surface-wave multiple-tap delay lines. The devices were coded to generate and correlate a 31 chip m-sequence with a 10 MHz PN rate. Of the four devices available, there were two sets of generator and matched filter. One set

Table 2. Listing of the Sequences

Initial Conditions. 0000001

F1	Polynomial	P/S
0	0000011	127.9
1	1000001	127:11
2	0001001	127:12
3	0010001	127:12
4	0001111	127:11
5	1110001	127:12
6	0011101	127:12
7	0111001	127:11
8	0100111	127:12
9	1100101	127:11
10	0101011	127:12
11	1010101	127:12
12	0111111	127:12
13	1111101	127:12
14	1001011	127:12
15	1010011	127:11
16	1101111	127:12
17	1110111	127:11

$(F_1 + 1)$ _ Eg _ $(17-F_1)$

Table 3. Cross-Correlation Peaks for $F_1 = 0$

E_g	Max Peak	Position
1	25	69
2	22	92
3	20	94,114
4	25	101
5	29	97
6	30	94
7	18	86,100,106
8	20	114
9	25	99
10	22	114
11	24	116
12	27	103
13	29	73
14	22	116,110
15	22	100
16	25	115
17	20	96

Table 4. Cross-Correlation Peaks for $F_1 = 1$

Lg	Max Peak	Position
1	21	97
2	21	83
3	23	101,127
4	20	106
5	22	118
6	20	64
7	23	101
8	19	101,99
9	40	120
10	26	108
11	34	108
12	22	114,110
13	22	118,116,90
14	25	125
15	22	78
16	28	104

Table 5. Cross-Correlation Peaks for $F_1 = 2$

Eg	Max Peak	Position
1	22	110
2	22	76
3	27	97
4	20	120,80,72
5	34	68
6	18	120,106
7	23	93
8	20	106,76
9	21	109
10	16	124,106,92
11	24	124
12	25	121,91
13	24	106
14	22	64
15	27	57

Table 6. Cross-Correlation Peaks for $F_1 = 3$

Eg	Max Peak	Position
1	26	40
2	20	74
3	35	87
4	22	108
5	34	94
6	23	87
7	21	111
8	19	87
9	42	108
10	19	109,43
11	20	116,90
12	24	108
13	26	100
14	21	111,77

Table 7. Cross-Correlation Peaks for $F_1 = 4$

Eg	Max Peak	Position
1	25	111
2	21	99
3	20	108
4	25	73
5	35	113
6	23	107
7	21	97
8	23	115
9	25	121,99
10	25	125
11	23	95
12	24	63
13	21	95

Table 8. Cross-Correlation Peaks for $F_1 = 5,6$

Eg	Max Peak	Position
1	20	52
2	22	74
3	26	54
4	22	114
5	21	117,111
6	21	109,93
7	27	111
8	21	95
9	20	118
10	27	83
11	39	117
12	23	91

Eg	Max Peak	Position
1	22	72
2	18	72,74,104,122
3	25	91
4	18	122
5	22	96
6	22	44
7	18	94,56
8	22	114
9	26	76
10	24	116
11	34	90

Table 9. Cross-Correlation Peaks for F_1 = 7,8

F_1 = 7

Eg	Max Peak	Position
1	20	106
2	21	89
3	24	114
4	30	94
5	20	98
6	18	102
7	24	126
8	21	95
9	22	96
10	21	105,97

F_1 = 8

Eq	Max Peak	Position
1	23	105,75
2	18	98
3	20	116,94
4	20	110
5	20	118
6	22	116
7	19	59
8	21	113
9	25	83

Table 10. Cross-Correlation Peaks for F_1 = 9,10,11

$F_1 = 9$

Eg	Max Peak	Position
1	23	107
2	29	101
3	25	103
4	19	91
5	20	118,102
6	21	65
7	27	81
8	22	68

$F_1 = 10$

Eg	Max Peak	Position
1	23	67
2	18	88,74
3	23	117
4	33	91
5	19	75
6	29	83
7	21	57

$F_1 = 11$

Eg	Max Peak	Position
1	26	108
2	21	109
3	22	118,56
4	23	127
5	25	77
6	22	50

Table 11. Cross-Correlation Peaks for $F_1 = 12,13,14,15,16$

$F_1 = 12$

Eg	Max Peak	Position
1	25	95
2	31	103
3	19	123,121,109
4	23	105
5	28	96

$F_1 = 13$

Eg	Max Peak	Position
1	21	101
2	24	58
3	24	108
4	21	105

$F_1 = 14$

Eg	Max Peak	Position
1	28	84
2	21	85
3	18	112

$F_1 = 15$

Eg	Max Peak	Position
1	21	75
2	26	92

$F_1 = 16$

Eg	Max Peak	Position
1	22	78

operated at 70 MHz and the other at 100 MHz. Figure 2 is a photograph of the 70 MHz device, and Figure 3 shows the sequence and auto-correlation pattern. Description of the devices and their operation is given in a previous report.[2]

In order to perform a cross-correlation experiment the 100 MHz and 70 MHz correlators were used. Since these devices contained identical tap phase coding, the experiment performed involved cross-correlating a sequence with its time inverse. The 100 MHz device was used to generate the sequence. Its frequency was mixed down to 70 MHz. Figure 4 shows the theoretical and experimental results. The predicted maximum cross-correlation peak is 11 units high compared to 5 for the maximum auto-correlation sidelobe. Figure 5 shows the operation of the 70 MHz correlator with the presence of both its matched sequence and inverse. Comparison of Figures 4 and 5 shows that the output of the surface wave matched filter is the sum of its responses to each sequence present.

The above result is very important, especially when considering a pure pseudo-noise or code division multiple access system. Tables 3-11 showed that cross-correlation can result in very high spurious peaks. It is conceivable that a particular receiver may be inundated with several simultaneous or slightly delayed transmissions from within the system. Depending upon range differences, Figure 5 shows that cross-correlation may produce missed synchronizations or at least seriously degrade the signal-to-noise ratio. This only adds to the seriousness of the "near-far problem" in a direct mode multiple access concept. It further points out that some form of discrimination against the sidelobes must be performed.

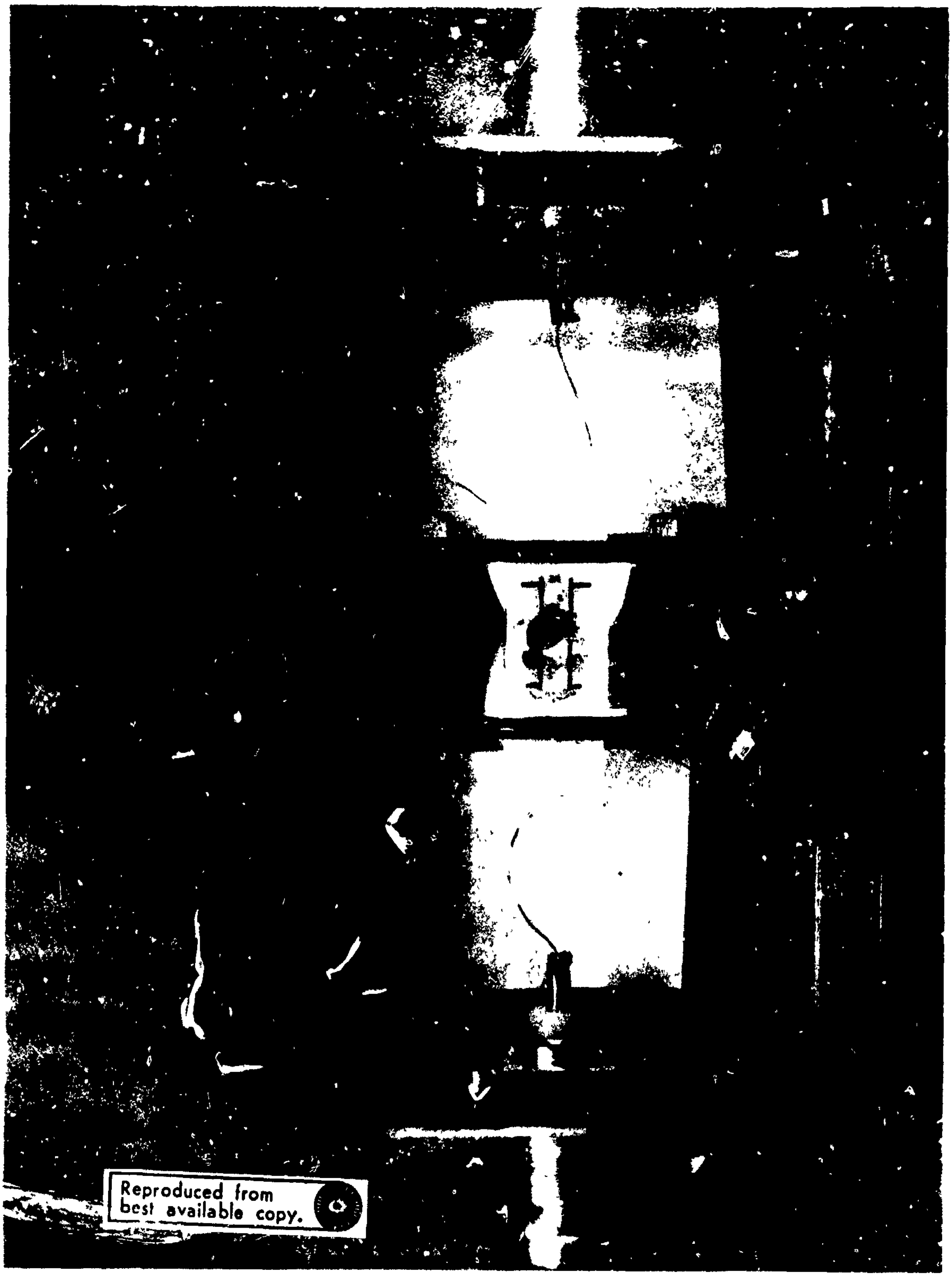


Figure 2. 70 MHz Surface Wave Device

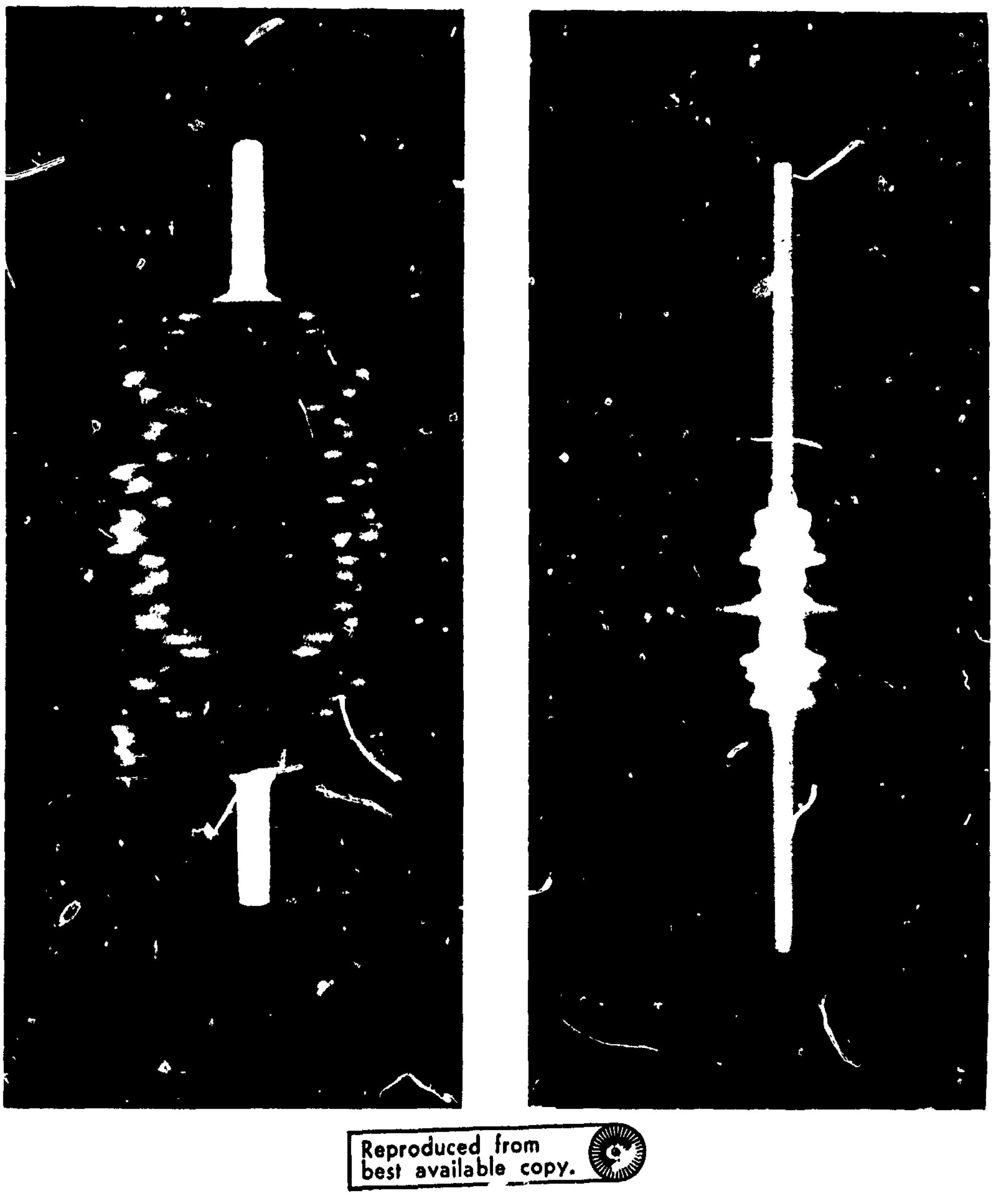
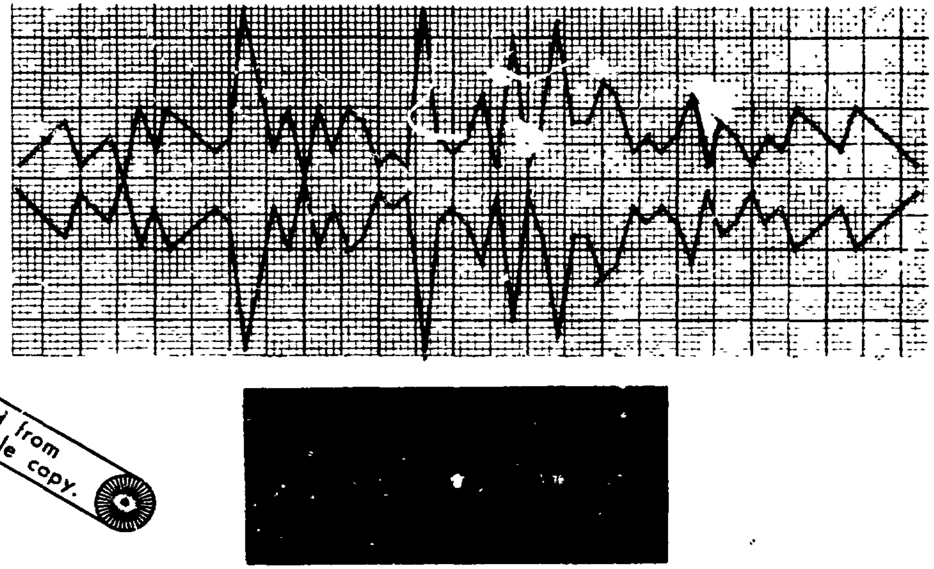


Figure 3. Sequence and Auto-Correlation Pattern



0000100101100111110001101110101 MATCHED FILTER TAP PHASES

1010111011000111110011010010000 SEQUENCE CHIP PHASES

DIRECTION OF CORRELATION

Figure 4. Cross-Correlation Properties

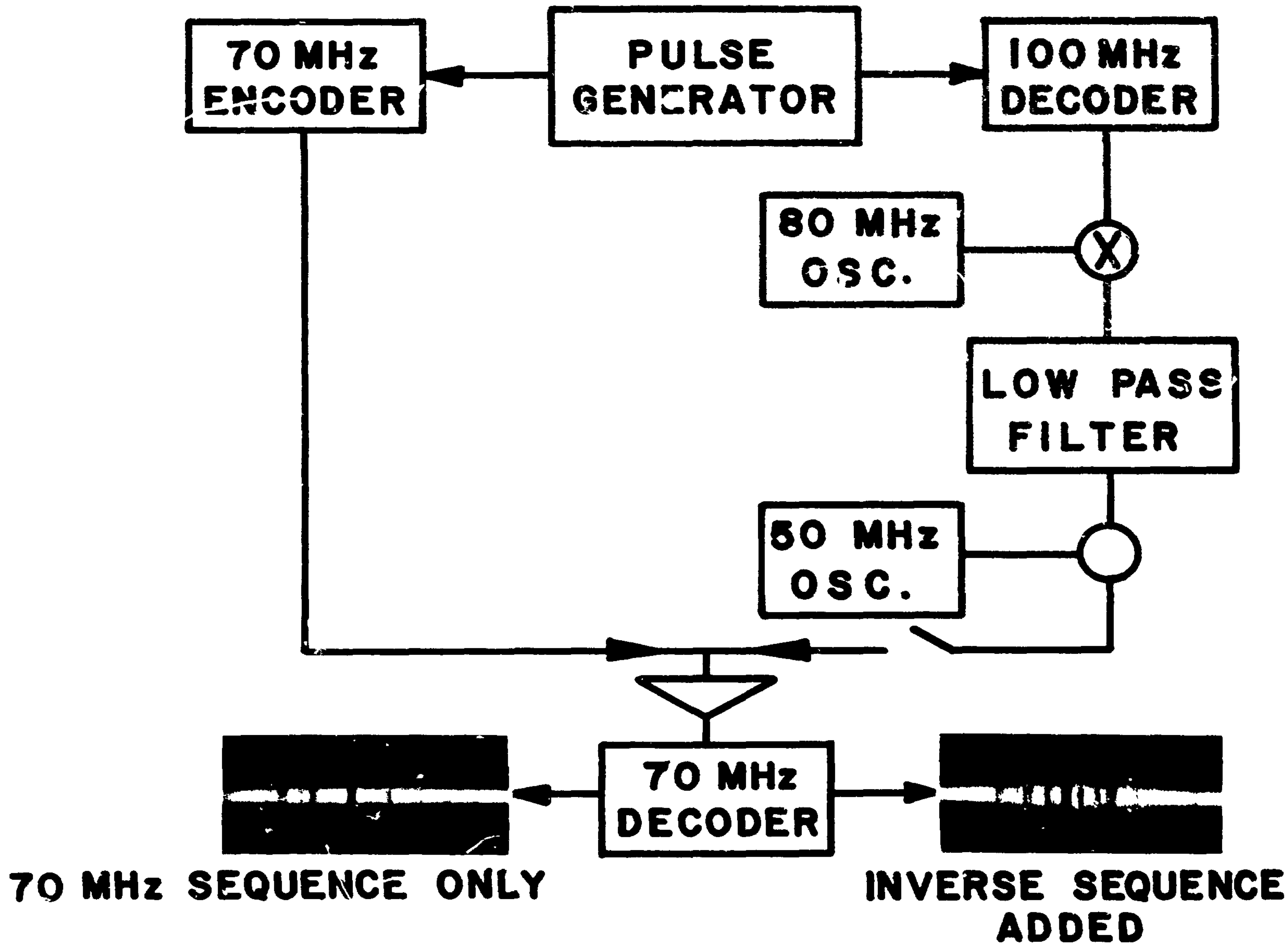


Figure 5. Correlation with Inverse Sequence Added

3. Multi-Path Effects

In studying the effects of multi-path, a simulator was utilized which provided control of delay and frequency selective fading rate. Because a rapid frame changing camera was not available, photographs were taken at specific times during repetitive transmissions of the sequence for particular path delay differences. The path delay difference was changed in steps equal to a chip period.

Figure 6 presents a theoretical plot of a two path propagation with 0.4 usec or 4 chip period delay. The correlation peak for zero delay (i.e., the first correlation peak observed) has decreased by one amplitude unit while the maximum sidelobe has increased three units and shifted position. Thus the maximum obtainable voltage processing gain has decreased from about 15.8 dB to 11.5 dB.

Figure 7 presents actual photographs of the two path propagation for various delays. As the delay increases from zero to 0.9 usec one can note the appearance of the second correlation peak and the decrease in peak amplitude. Figure 8 is an expanded view of the 0.9 usec path difference.

Comparison of Figure 6 and the 0.4 usec path difference photograph in Figure 7 shows similar sidelobe structures. However, the peaks are not resolved and their amplitudes are unequal. This can be attributed to the inductive matching of the surface wave devices, which has caused band limiting. The spreading of the peaks due to band limiting is seen more clearly in Figure 8. Although there is a reduction in correlation peak amplitude due to the multipath, the use of a PN sequence does allow rejection of arrivals delayed by more than one chip.

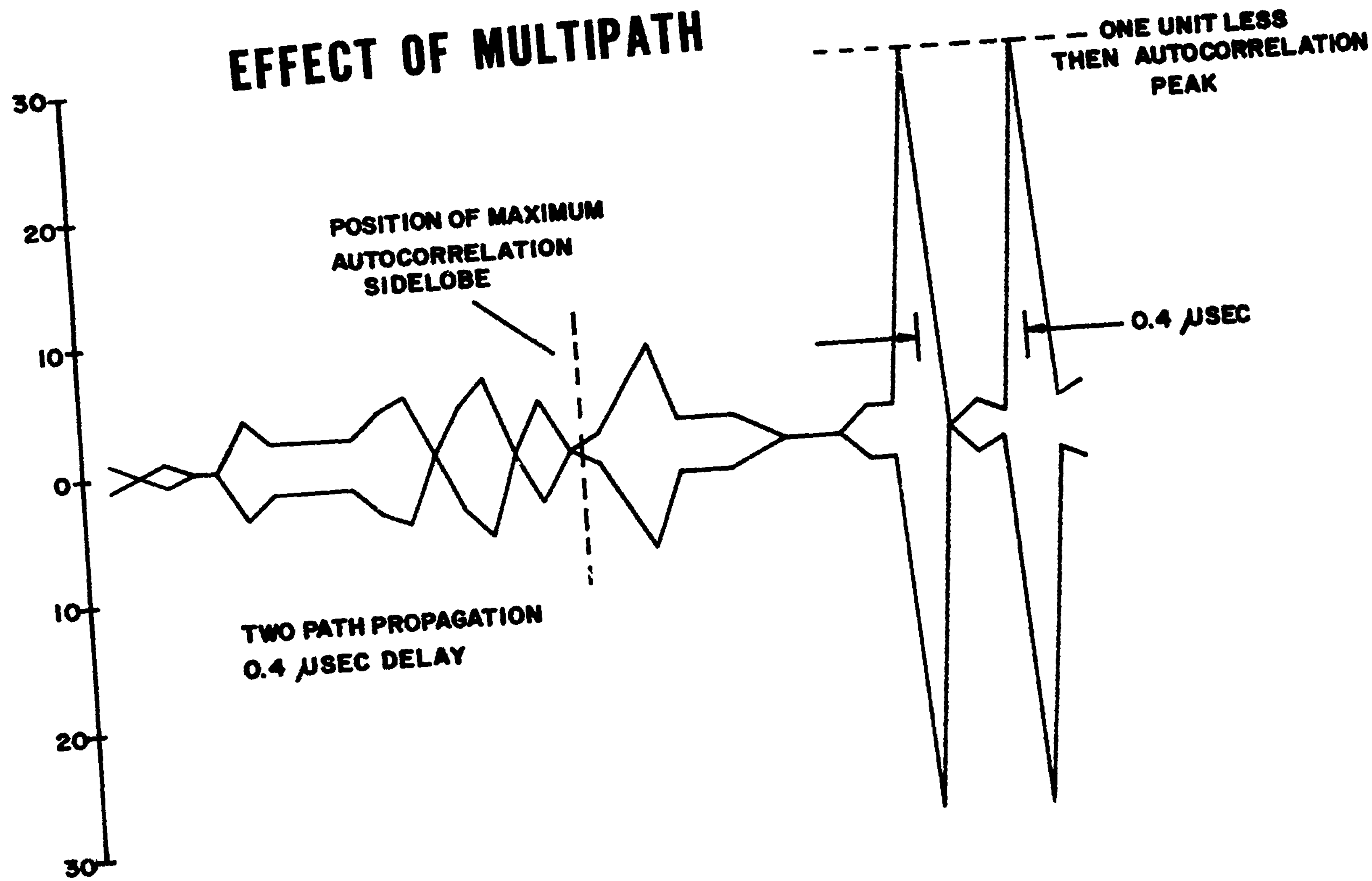


Figure 6. Two Path Propagation

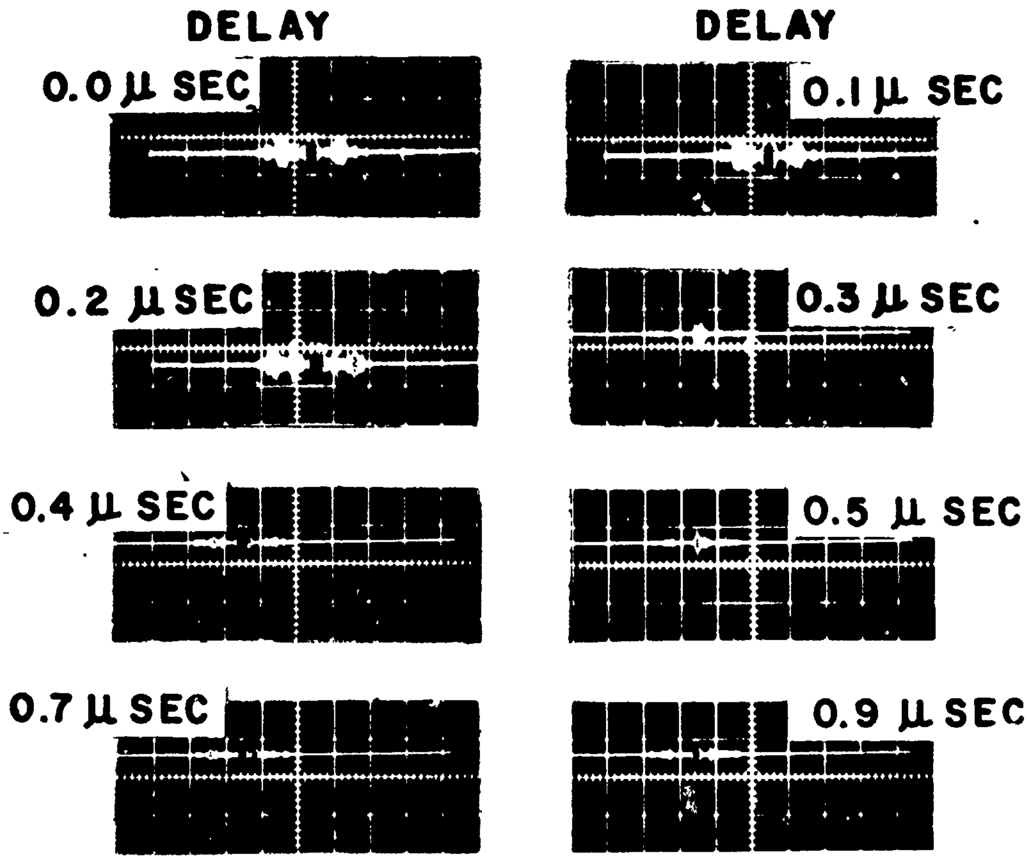


Figure 7. Multipath Experiments

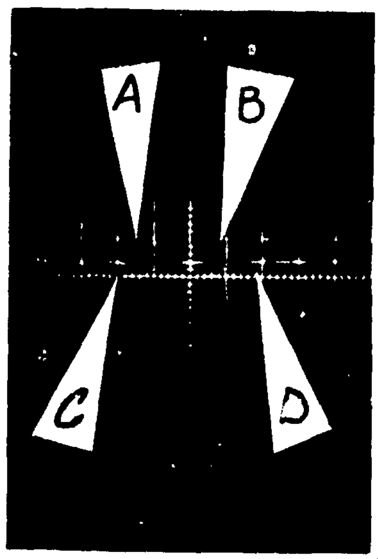


Figure 8. Expanded View of 0.9 usec Delay

1 1/4 min into Transmission

A to B = 0.9 μsec
C to D = 1.5 μsec

4. Conclusion

From the point of view of resolving synch, it must be noted that the binary sequence provides auto-correlation properties sufficient to reject multipath delays larger than one chip. From this point of view then, a pseudo-noise binary sequence provides desired performance.

From the point of view of discriminating a desired signal from unwanted signals, the cross-correlation effects observed and computed are not very encouraging for a pure code division system. The possibility of cross-correlation sidelobes from 5 to 9 dB below the auto-correlation peak does not make for a bright picture when one considers that operation may be required for near-far user ratios of 80 to 100 dB. It is obvious that some additional system government must be added to reduce the severity of these interferences while maintaining discrimination against multipath.

The use of TDMA in combination with the pseudo-noise presents desirable characteristics and has been proposed for multiple access systems using satellite repeaters.[8]

IV SPECIFICATION OF A SYNCHRONIZATION PROCEDURE AND A CODE

1. General Remarks

As noted by Cahn, et. al.[3] a possible usable waveform for a direct mode, multiple access system is a hybrid combination of frequency hopping, time hopping and binary pseudo-noise. The system would be time coordinated. Thus, there would be rough timing information between transmitter and receiver, and the synchronization procedure could provide highly accurate ranging data in addition to lock-up.

The suggested synch procedure, and the one concerned with in this report, is to transmit a short header or preamble at the beginning of each message frame, as illustrated in Figure 1. Since we are concerned with multiple access situation, the preamble would be coded and perform part of the addressing function.

In the system, each user would be assigned a time slot for transmission within the major time frame of the system. In combination with frequency division, each time slot would be occupied by a number of users, each at a different frequency. When pseudo-noise is included, coding also provides user separability. In a time hop, frequency hop system, the slot position and frequency are pseudo-randomly permuted. Such a system minimizes the effects of strong nearby emitters.

In the system, each transmitter is assigned a time slot but no frequency. Each receiver is assigned a frequency hopping pattern but no time slot. Referring to Figure 1, the frequency hops between time frames. The frequency hop pattern and preamble code act as the receiver's address.

2. Advantages of Frequency Division

To show how the addition of a frequency separation can provide a vast improvement in the synchronization procedure as compared to pure coding, the experiment illustrated in Figure 5 was rerun. However, in this case the frequency of the inverse sequence was kept at 100 MHz. The equal strength sequences were combined and the sum was applied to both correlators. The results are shown in Figure 9. Neither sequence has interferred with the correlation process of the other's matched filter. In fact, if the same sequence at two different frequencies

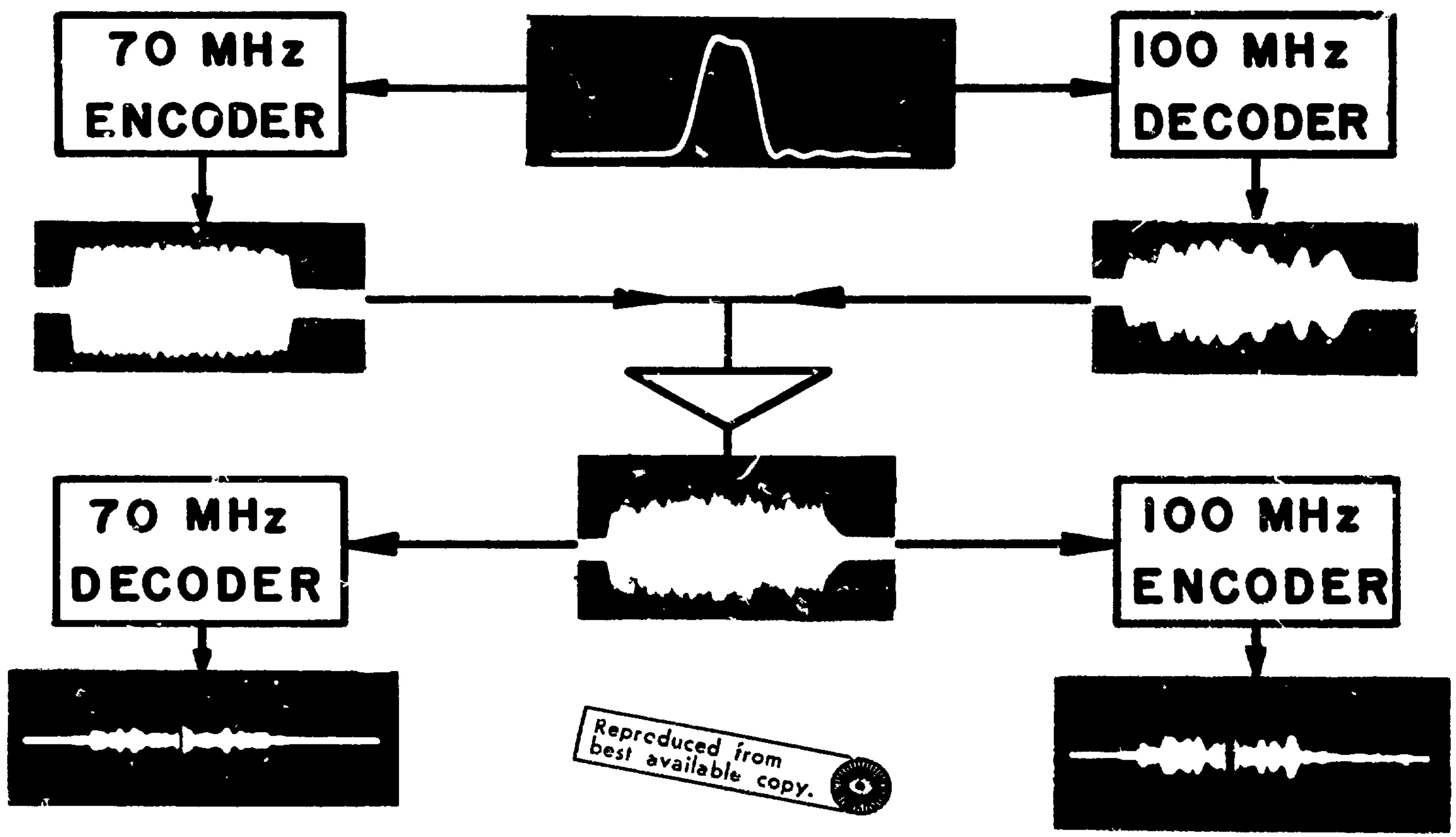


Figure 9. Correlation of Sequence and Inverse with Frequency Separations

is summed and impressed on the matched filter, no degradation in the peak-to-sidelobe ratio is encountered. This result is shown in Figure 10. The situation depicted in Figures 9 and 10 may be interpreted as that of two users transmitting to two receivers such that the two synch preambles arrive at each receiver with equal strength. The performance of the acoustic surface wave matched filters and the code is highly successful.

The desirability of frequency division can also be seen when one attempts to interfere with signal reception. Figure 11 shows the result of adding 70 MHz Gaussian noise to the 70 MHz sequence. A diode detector was used for this picture. It can be noted that at input S/N = -10 dB, missed synchronizations can occur because of the oscillation of the correlation peak. However Figure 12 shows that there would be no interference with other users unless the S/N for that user becomes very poor. The proper use of front-end limiters may preclude this last possibility from happening.

3. Minimum Frequency Separation

The obvious question at this point is how little frequency separation is tolerable? It has been estimated that, as long as the frequency separation is larger than one over the sequence length, there will be no interaction for like coded sequences. The pseudo-noise modulation rate determines the bandwidth and, for frequency hop or frequency division concepts, is usually chosen as the minimum separation. Therefore, for the 31 chip m-sequence used in the experimentation, one would expect an interaction between the correlator and an offset

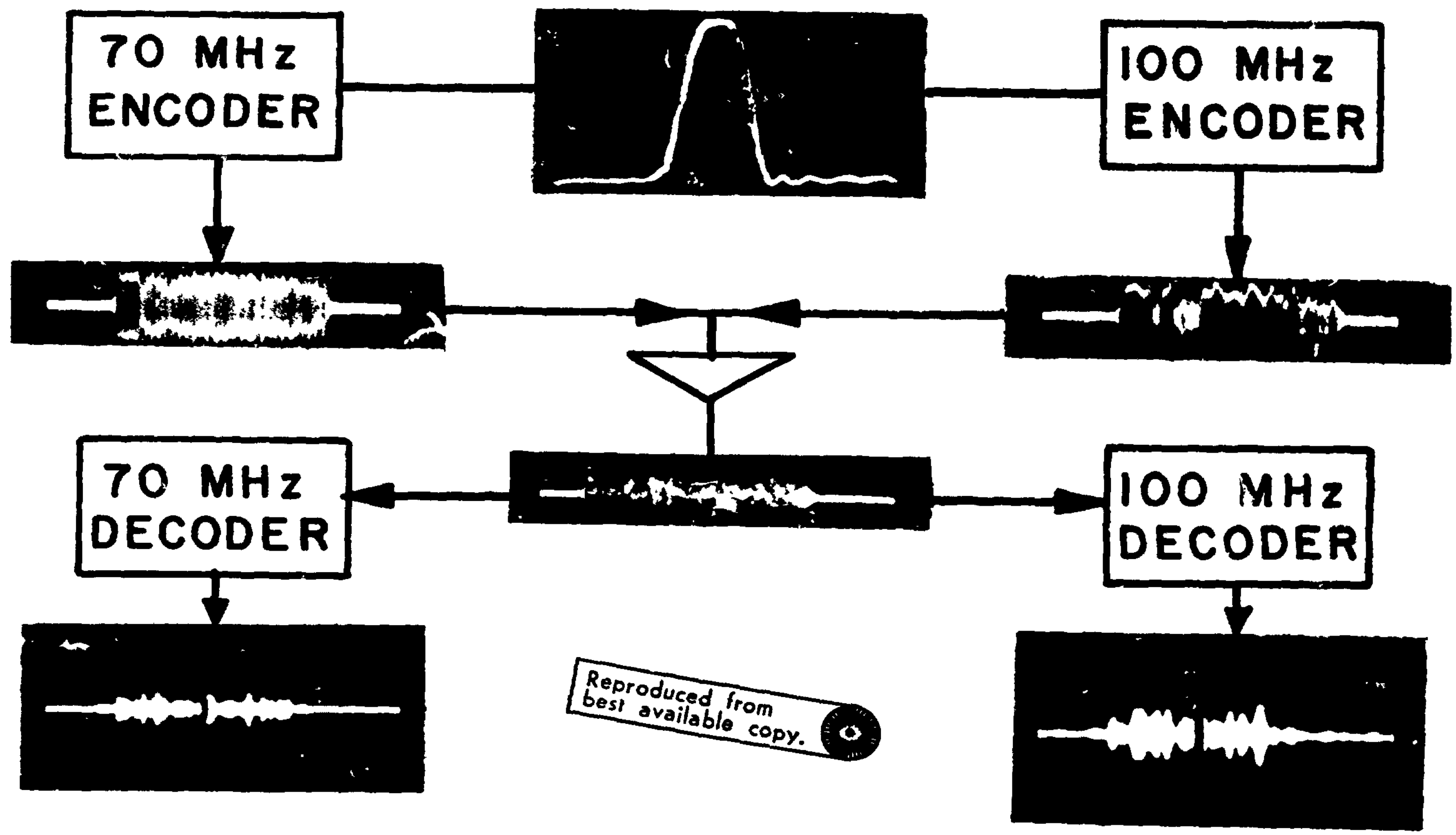


Figure 10. Correlation of Same Sequence at Two Frequencies

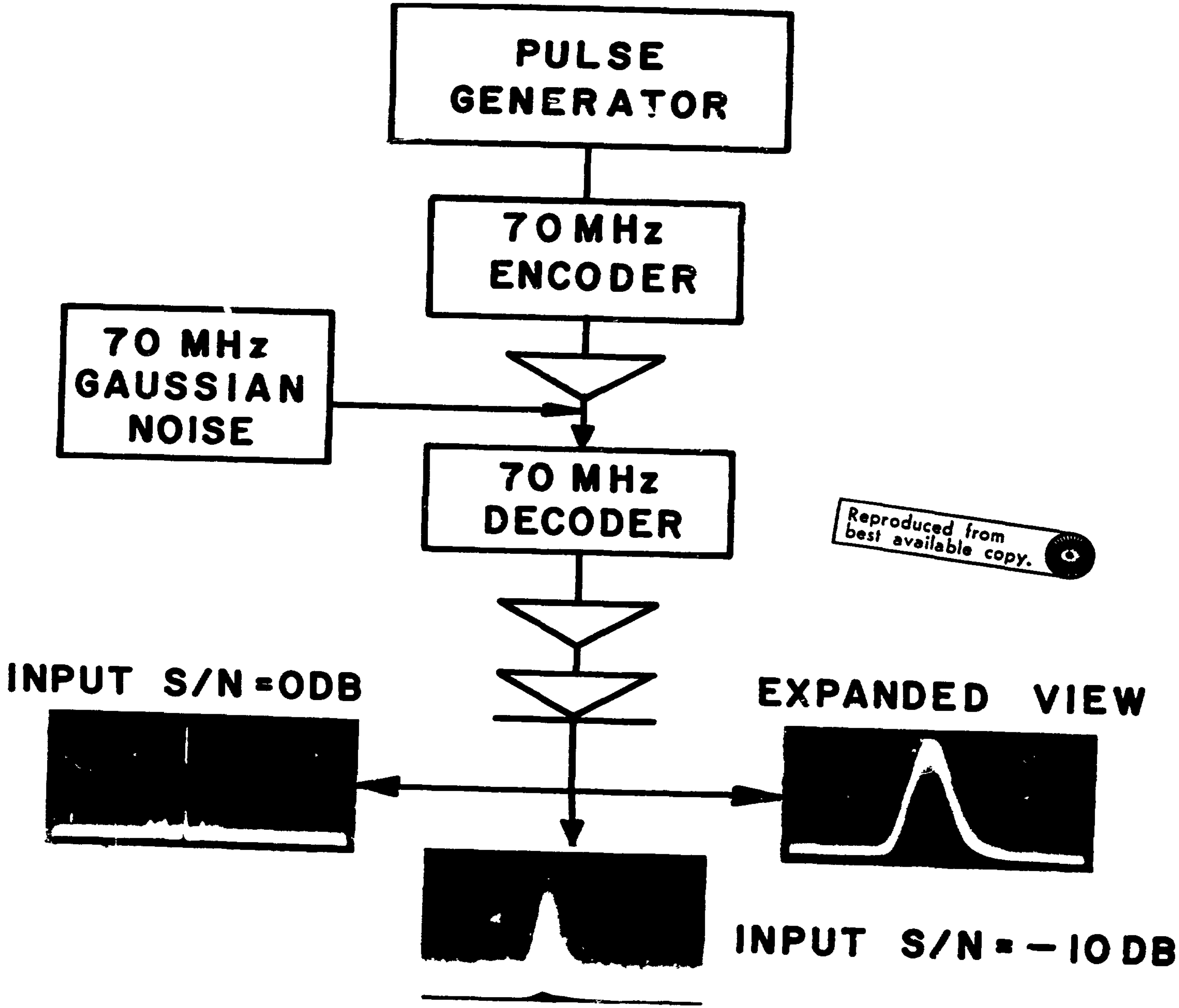


Figure 11. Effect of 70 MHz Gaussian Noise on 70 MHz Correlation

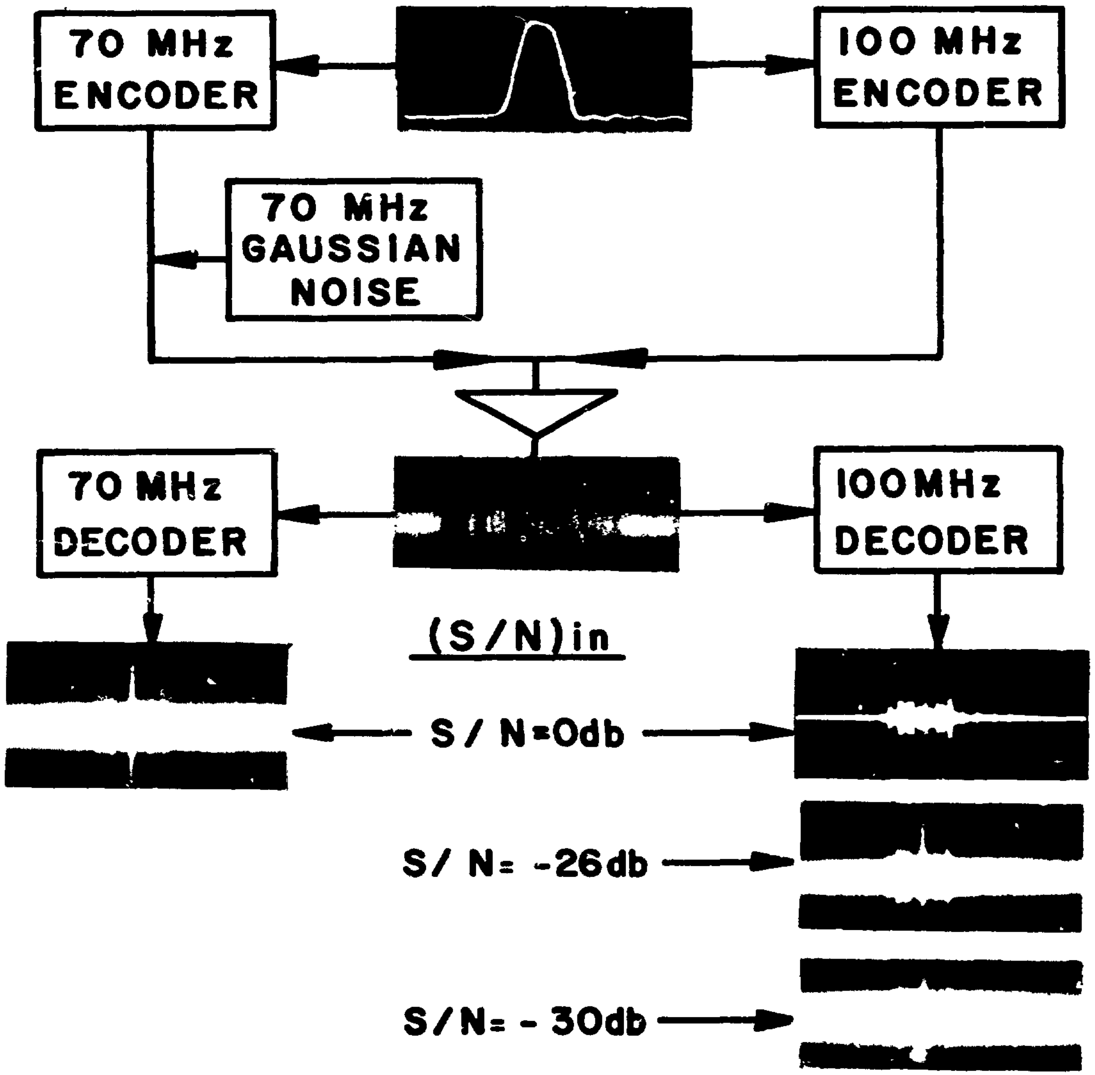


Figure 12. Correlation of 100 MHz Sequence in Presence of 70 MHz Gaussian Noise

sequence over a bandwidth of 600 kHz since the sequence is 3.1 usec in length. Indeed, this was found to be true. Shifting the frequency of the generated sequence about the 70 MHz resonant frequency of the surface wave matched filter, unity correlation peak-to-sidelobe ratio was obtained at points approximately $\pm$300 kHz. That is, one could not distinguish a correlation peak in the matched filter's response. At this point the like coded sequence, at a frequency of 70 MHz, was added, and the combination was fed to the matched filter. There was no degradation in the correlation peak-to-sidelobe ratio. Using essentially identical surface wave devices, Carr et. al.[7] also found peak-to-sidelobe ratios of less than 1 dB at points $\pm$300 kHz.

For offset frequencies beyond 300 kHz, there was no correlation peak discernable and the response of the correlator was noiselike with peaks occuring at a various positions. When this frequency offset sequence was combined with its like coded sequence of 70 MHz and then correlated by the 70 MHz matched filter, it was found that the peak to noise ratio was less than the correlation peak to maximum sidelobe ratio for the 70 MHz sequence only. For offset frequencies beyond -5 MHz and +3 MHz the S/N ratio became equal to the correlation peak to maximum sidelobe ratio. The frequency offset sequence could be assumed to be another user in the same time slot generating a preamble sequence.

In an actual system, however, no two addresses would be the same. To study the above situation in a more realistic manner, the inverse sequence was used, and its frequency was shifted relative to the resonant

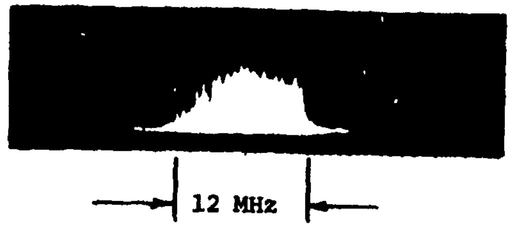
frequency of the matched filter. The results were the same. That is, the peak-to-noise ratio improved to become equal to the peak-to-sidelobe ratio outside of the offsets -5 MHz and +3 MHz.

Since the PN modulation rate was 10 MHz, the above results would indicate that a frequency separation of one half the PN rate is sufficient to prevent system self-jamming or user mutual interference. However, it must be noted that to reduce the insertion loss of the devices, both input and output transducers were inductively matched. This resulted in a reduction of the bandwidth of each device. Thus, less than a 10 MHz bandwidth was being used. As shown by Figure 13, the responses are no longer a nice $\sin^2 x/x^2$ allowing for a smaller frequency separation. It would be safe to say therefore that the frequency separation should indeed be equal to the instantaneous bandwidth.

4. Conclusions

It has been experimentally shown that the addition of frequency division to pseudo-noise provides an effective means for reducing both user mutual interference (i.e., near-far) and outside intereference for a direct or non-satellite mode multiple access system. When the frequency division takes the form of pseudo-random frequency hopping, an additional amount of resistance can be added.

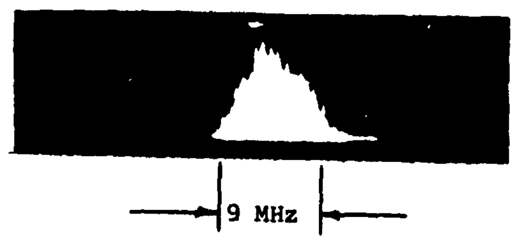
The reduction of system self-interference results in adequate performance of the synchronization preamble concept. In addition, the use of bi-phase, pseudo-noise modulation, for the preamble provided successful performance. In fact, the combination of bi-phase sequences and matched filters may even be successful for data modulation/demodulation techniques.



ENCODER PULSE RESPONSE

Input Pulse: 5 Volts, 10 nsec

40 Db Amplification

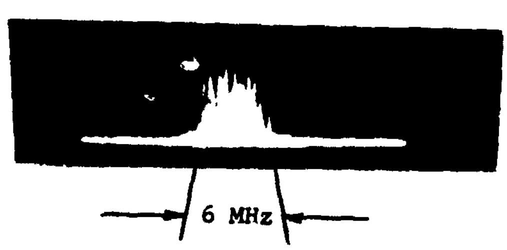


Decoder Pulse Response

Input Pulse: 5 Volts, 10 nsec

40 Db Amplification

Spectrum Height 8 Db Greater Than Encoder



Correlation Peak Spectrum

40 Db Amplification

Figure 13. Spectrum Analyzer Views of Responses

The performance of the acoustic surface wave multiple tap delay line as sequence generator and matched filter provides great encouragement when one becomes concerned with implementation of the waveforms. The technology has been developed to the point where implementation of the preamble can be simply accomplished at very low cost. The experiments conducted for this report utilized fixed frequency, fixed code surface wave devices. However, a study at RADC resulted in a technique to provide the required phase coherent frequency hopping as well as the capability to randomly switch the coding structure of the preamble.[9] This technique is currently being demonstrated.[10,11] Although the technique will not be described here it is suffice to say that the combination of solid state switches and acoustic surface wave devices allows a simple straightforward implementation.

V THE GROUND CONTROL TERMINAL IN A NET CONCEPT

The use of frequency division or frequency hopping provides adequate user separability as well as anti-jam synchronization procedures. Time division or time hopping provides increased orthogonality as well as strong system government. The hybrid FH/PN/TH, then, is quite a desirable waveform.

This type of waveform conveniently leads to a "net" concept for a direct (non-satellite) mode multiple access system. A net comprises a particular frequency hopping pattern, and only one user in a given net is transmitting. A net concept is illustrated in Figure 14.[3] The receiver being addressed auto-correlates the transmitted synch preamble which provides the synchronization for the data demodulation. At all

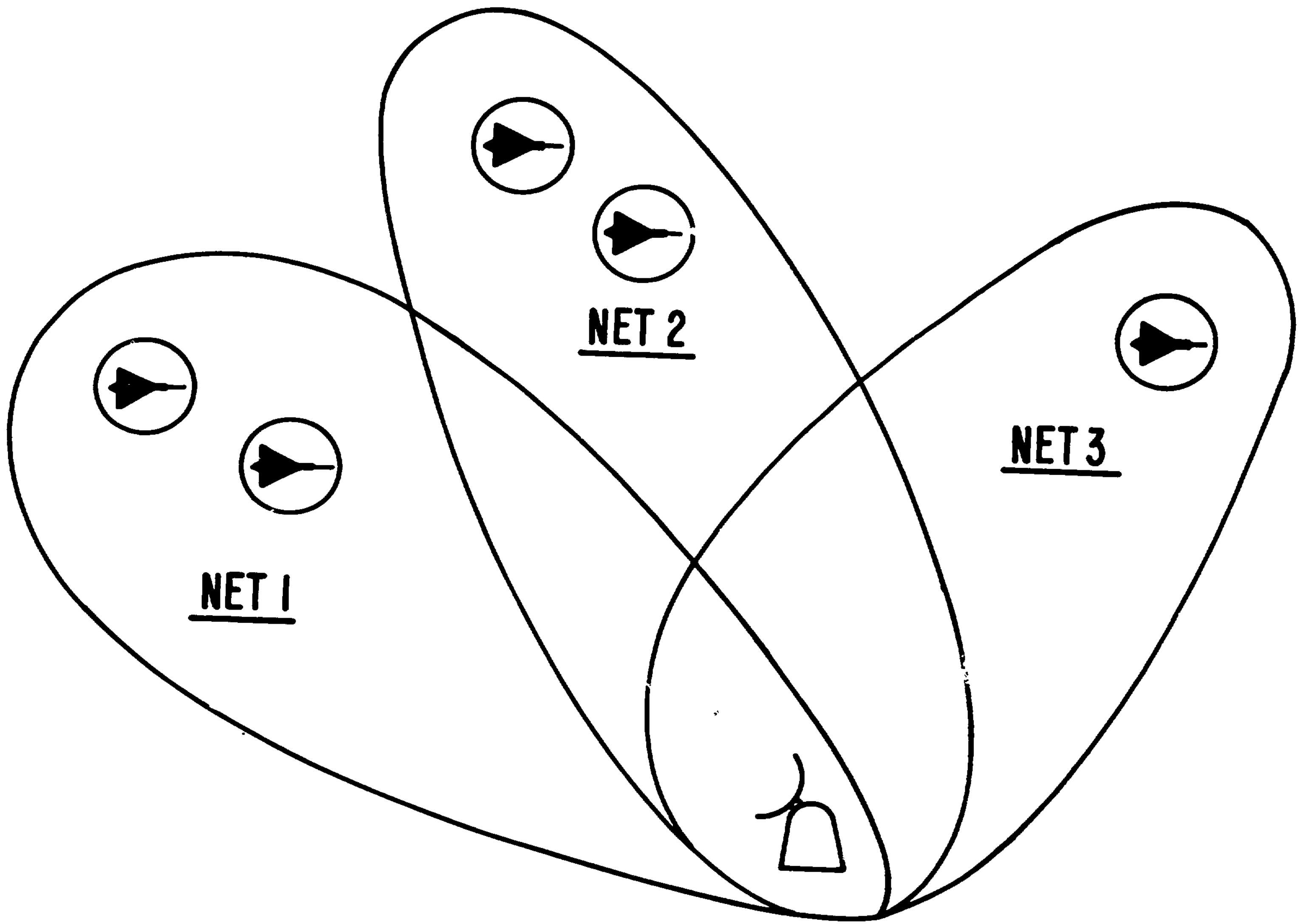


Figure 14. A Net Concept

other receivers in the net, the synch sequence transmitted is cross-correlated. As shown previously, this process should not effect a threshold crossing to establish an erroneous synch.

The situation is not as simple for the ground control terminal which may be within several nets. This terminal may receive simultaneous queries from the different nets. However, the system government would require that in each time slot, each net will be at a different frequency, separated by the proper amount as discussed above. Figure 10 showed that surface wave matched filters are capable of separating the same sequence at different frequencies. Thus, it will not be necessary to require that the ground control terminal contain a receiver for each of its nets. A single set of acoustic surface wave matched filters and a switching matrix can provide the synch function to all nets by parallel processing. This is shown conceptually in Figure 15. The frequency hop synthesizer or some such control unit connects the nets to the proper matched filter through the switching matrix. The synch outputs can then be used to turn on the demodulator for the net that has established the synch. Although not presently available, data modulation/demodulation techniques with surface wave matched filters are being studied and may allow a single set to perform all signal processing functions. Such an approach to implementation of the waveform is required.

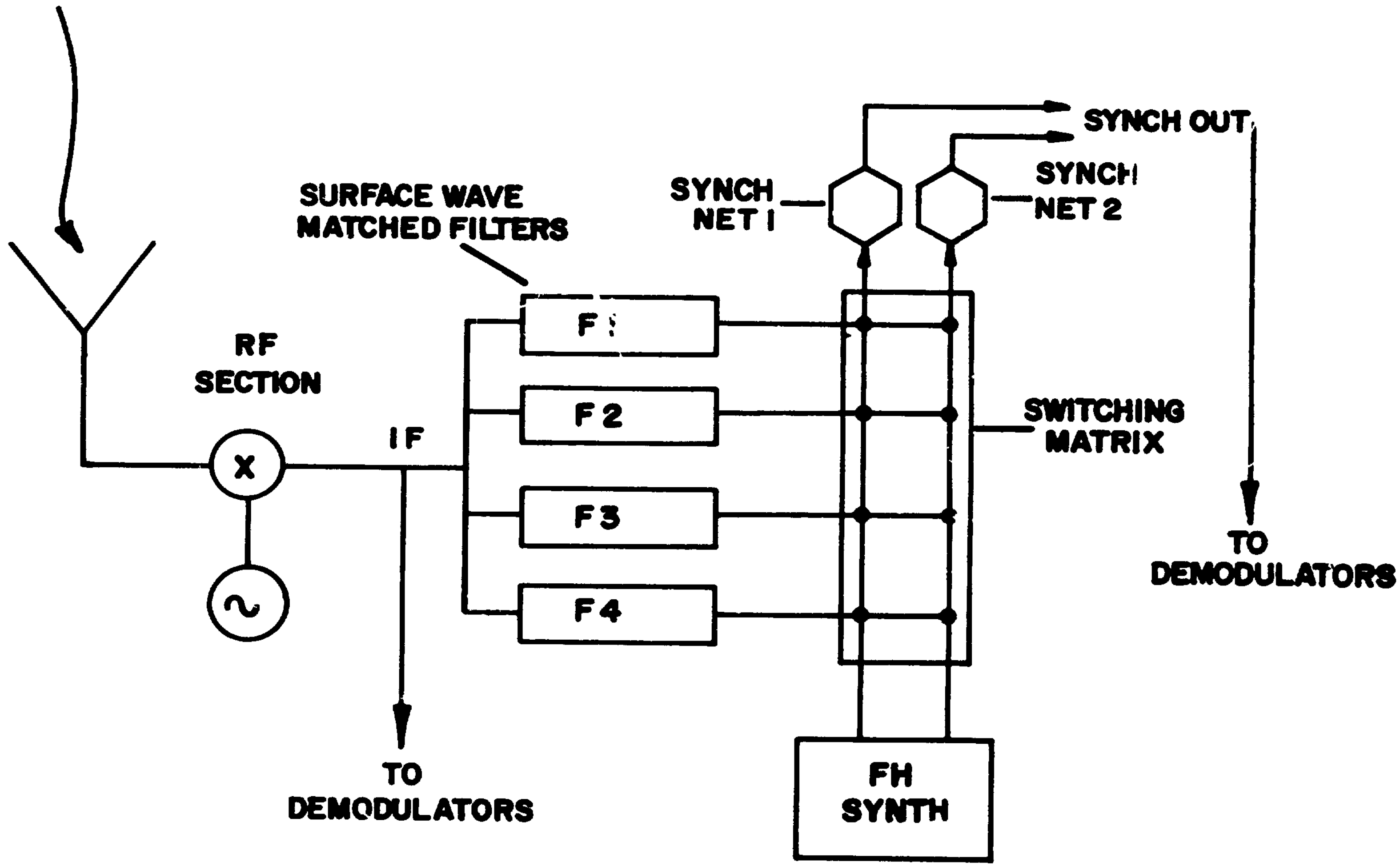


Figure 15. Ground Control Terminal Synch Implementation Concept

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13 ABSTRACT

~~This~~ report describes a study into synchronization problems of various spread spectrum waveforms for direct mode, multiple access systems. Particular attention is paid to user mutual interference and how this interference influences the choice of the waveform. Computer generated cross-correlation properties of the 18 basic 127 chip m-sequences are given in simulating a pure code division system.

The basic pseudo-noise sequence is implemented by acoustic surface wave matched filters. The performance of these matched filters under various interference conditions (including multipath) is given.

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Matched filters						
Spread spectrum						
Acoustic surface waves						
Synchronization						
Correlation						